Microwave remote sensing of rain-on-snow events in the subarctic with AMSR2 & GPM observations

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Context about rain-on-snow events

(IPCC 2013)

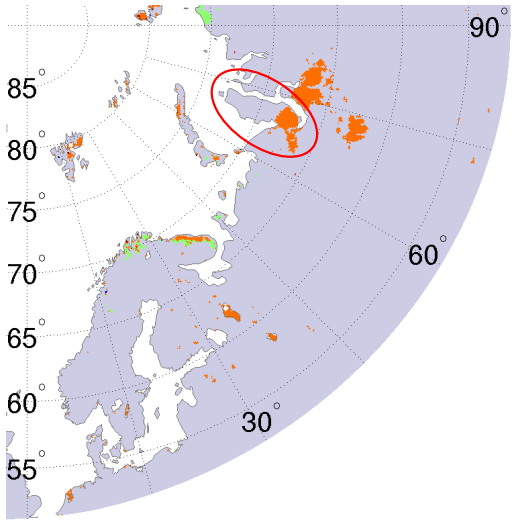
"The rapid rate at which climate is changing in the Polar Regions will impact natural and social systems."

"More frequent rain-on-snow events caused by warmer winters may restrict access to vegetation and may have profound negative influences on the population dynamics of Arctic ungulates."

Web of Science: 135 articles on rain on snow since 1985, 40% published since 2010

Context about rain-on-snow events

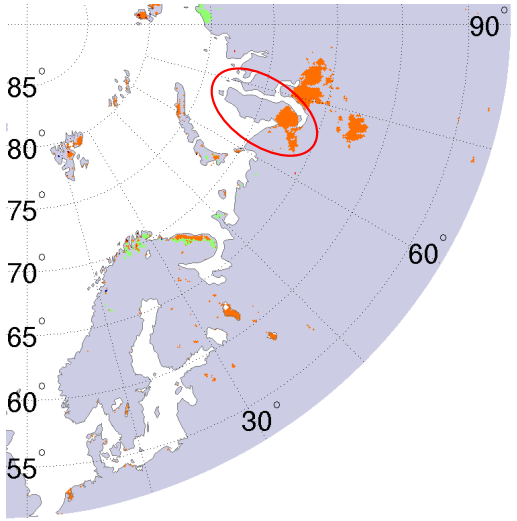
Rain on Nov. 8, 2013.
Picture taken on March 15, 2014.



AMSR2 detection on Nov. 8

Context about rain-on-snow events

Last winter, ∼100,000 reindeer died on the Yamal Peninsula, because they could not break through the ice to graze.



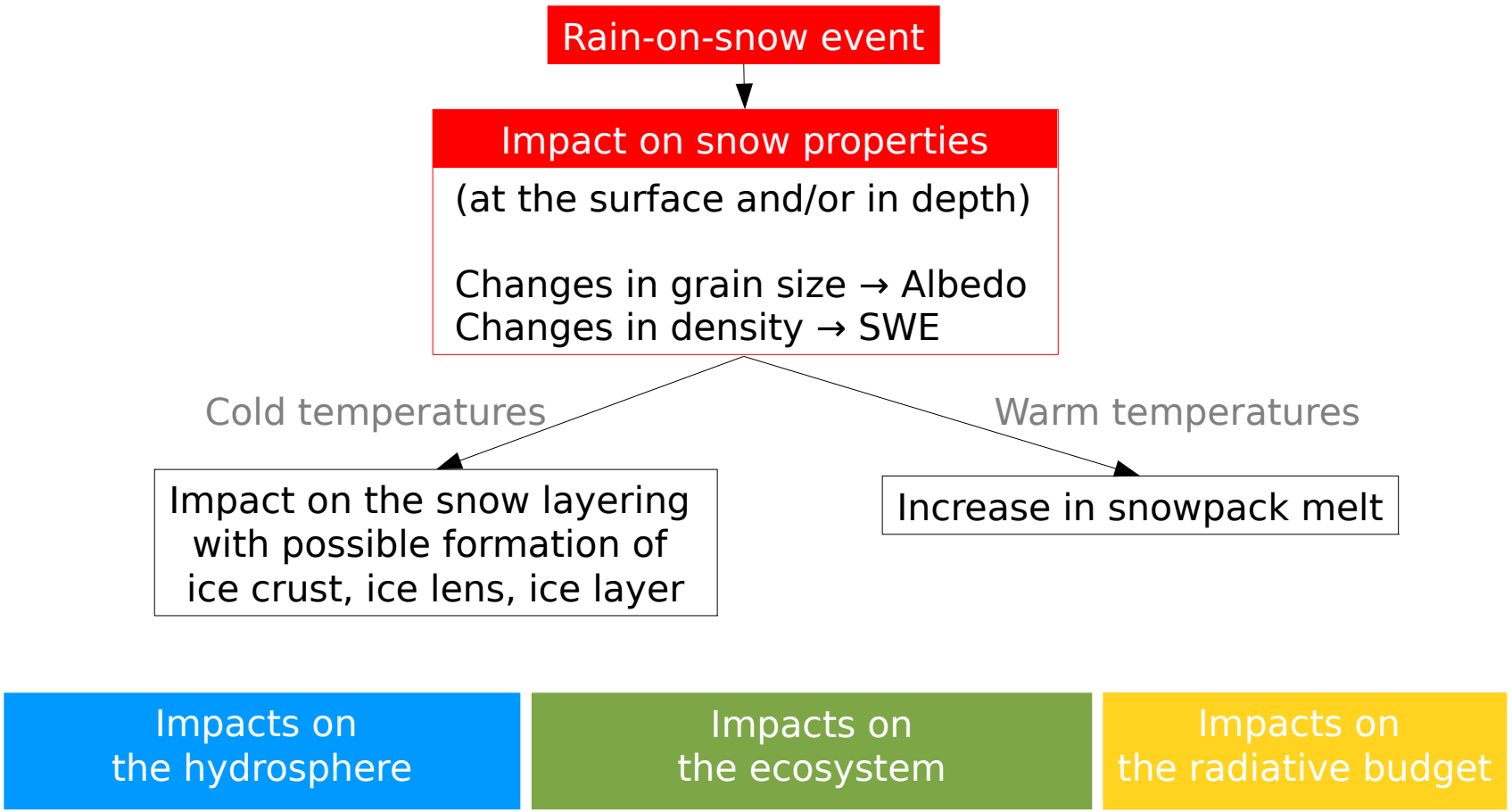
AMSR2 detection on Nov. 8

Why monitor rain-on-snow events?

Relevant for:

- Climate adaptation to improve decision-making (e.g. herd management)
- Wintertime climate change monitoring
- Increasing our knowledge of their impacts

Why monitor rain-on-snow events?



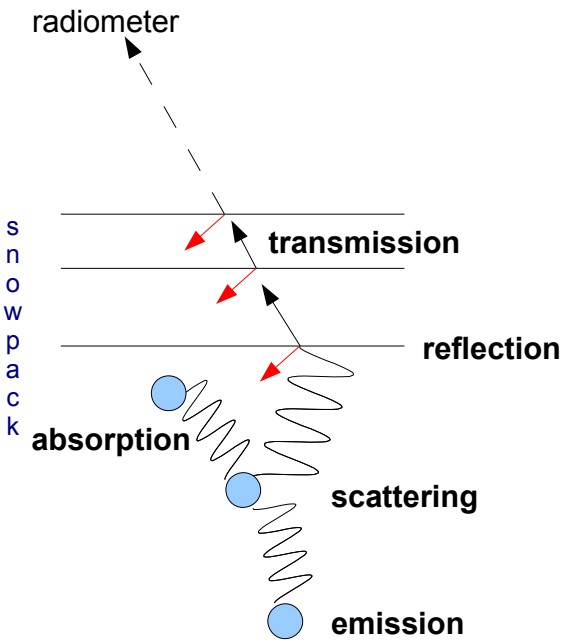
Question: Can we detect rain-on-snow events from microwave satellite observations, *especially* events leading to the formation of an ice layer?

Outline

1. Microwave emission simulations with DMRT-ML
2. A prototype algorithm to detect rain on snow with AMSR-E/2
3. GPM active/passive microwave observations
4. Conclusion

DMRT-ML – Elements

Dense Media Radiative Transfer - Multi Layers model



DMRT-ML computes:

- . emission
- . scattering
- . absorption

} **using the DMRT theory**

DMRT-ML computes the reflection coefficients at:

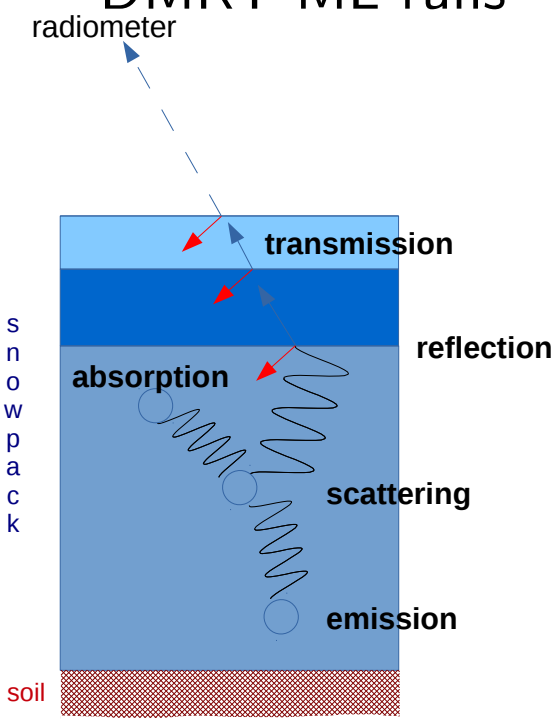
- . snow/snow interfaces
- . snow/atmosphere interface

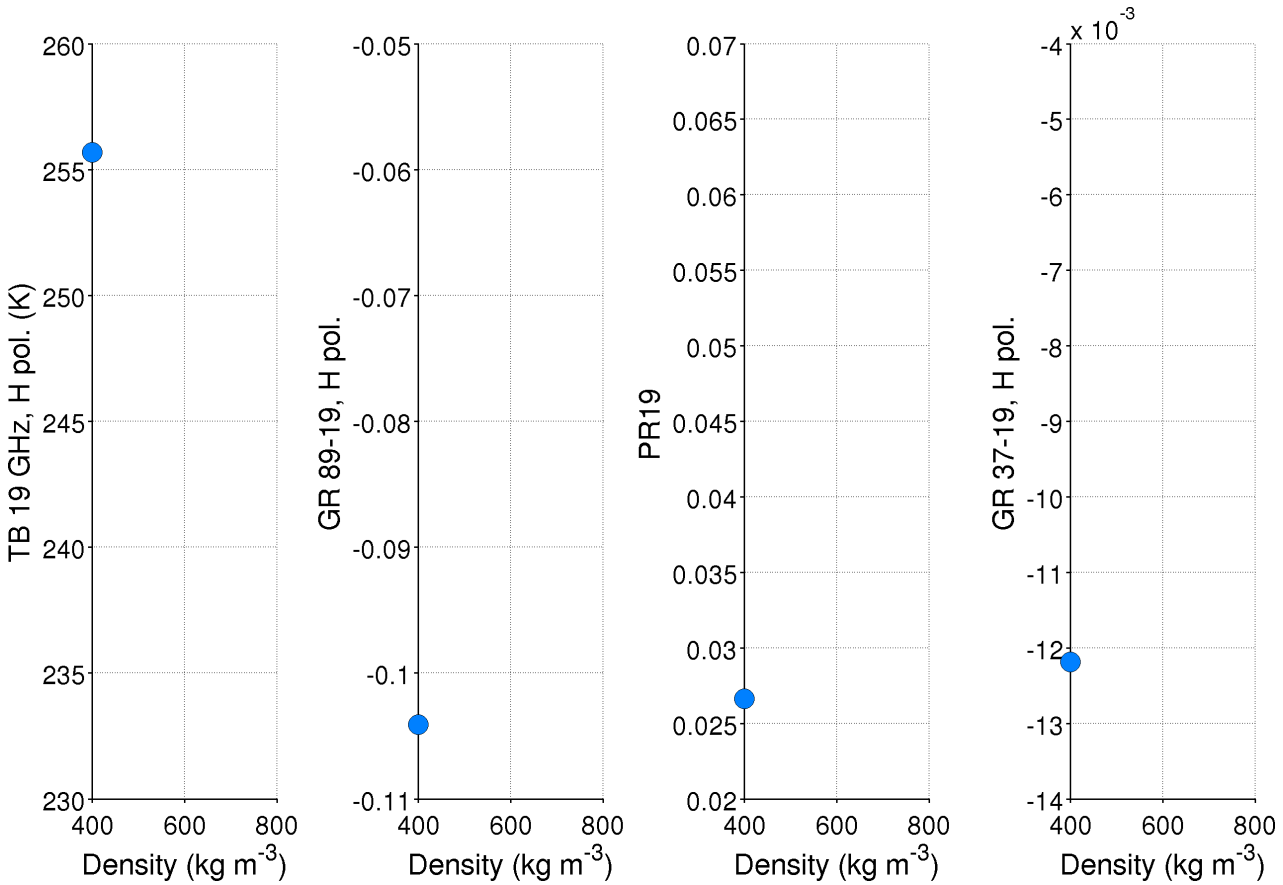
} **using Fresnel**

DMRT-ML solves the radiative transfer equation **using the DISORT method**

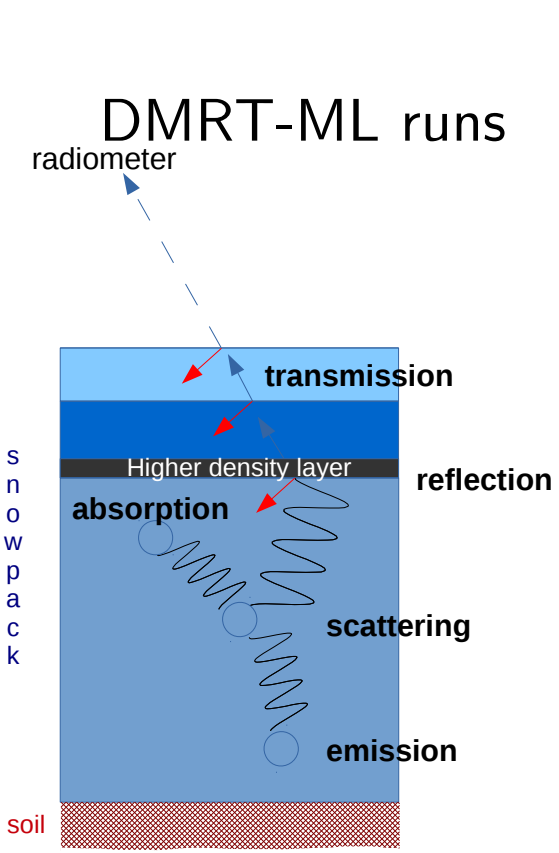
Picard, Brucker, Roy, Dupont, Fily, Royer, Harlow, Simulation of the microwave emission of multi-layered snowpacks using the DMRT theory: the DMRT-ML model. Geosci. Model Dev., 2013

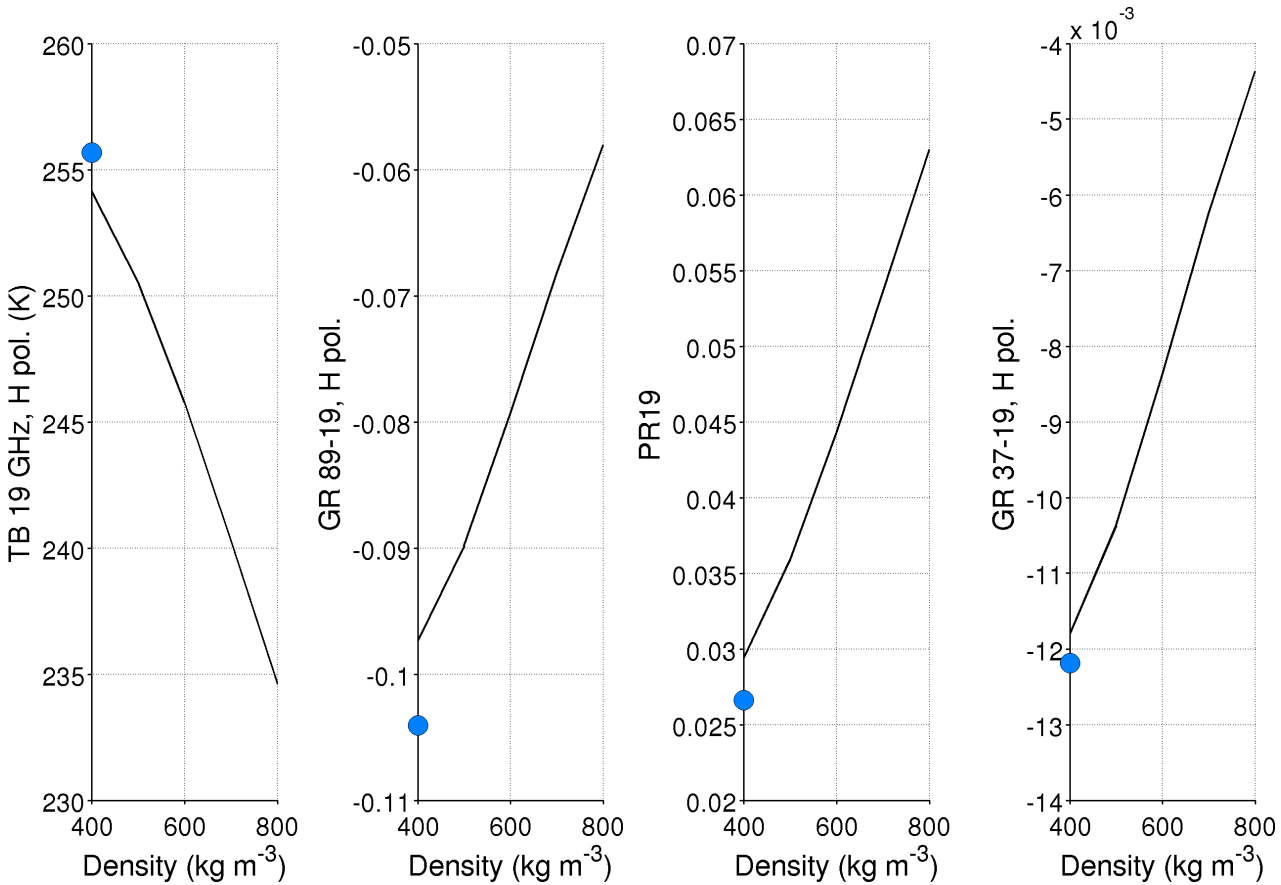
Simulated response to the formation of an ice layer on TB





Simulated response to the formation of an ice layer on TB





Modeling shows that the selected variables respond to an increase in density

The vertical position of the denser layer matters *(Montpetit et al., TGRS 2013)*

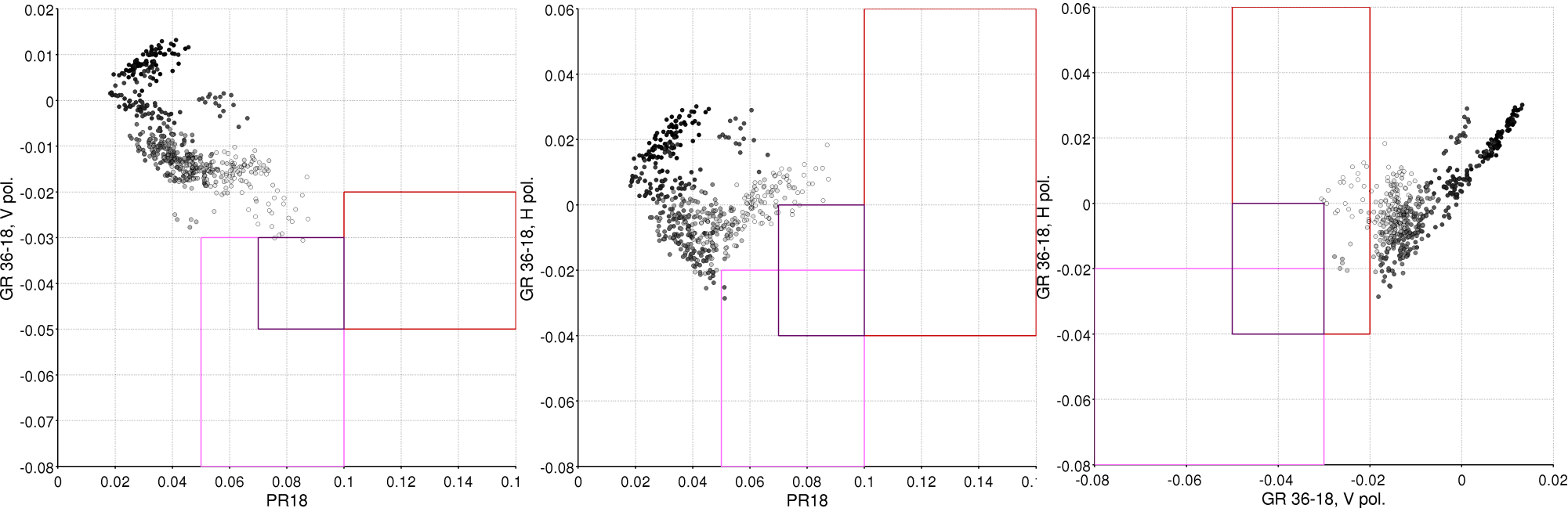
Prototype algorithm

A **prototype** algorithm was developed:

- It uses frequencies 19 – 89 GHz
- It is an empirical algorithm
- Leveraged Grenfell and Putkonen's (JGR 2008) spectral detection
- Added a temporal detection

Prototype algorithm – Spectral detection

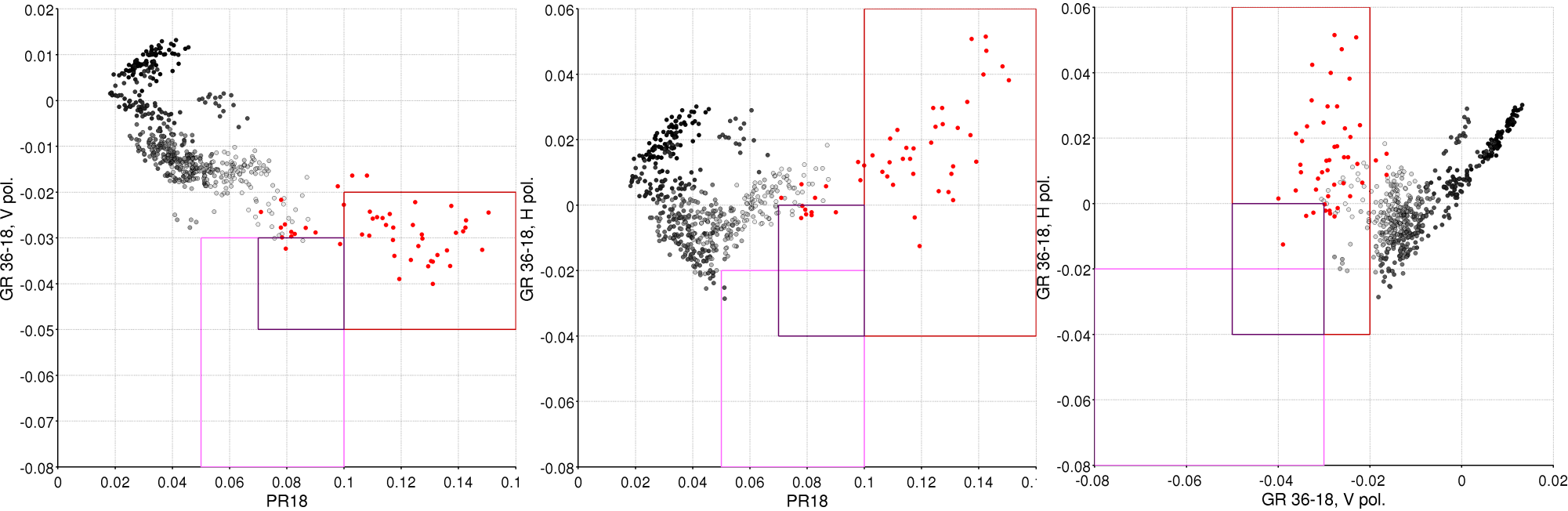
Banks Island, 2003



During 1 month before the ROS event

Prototype algorithm – Spectral detection

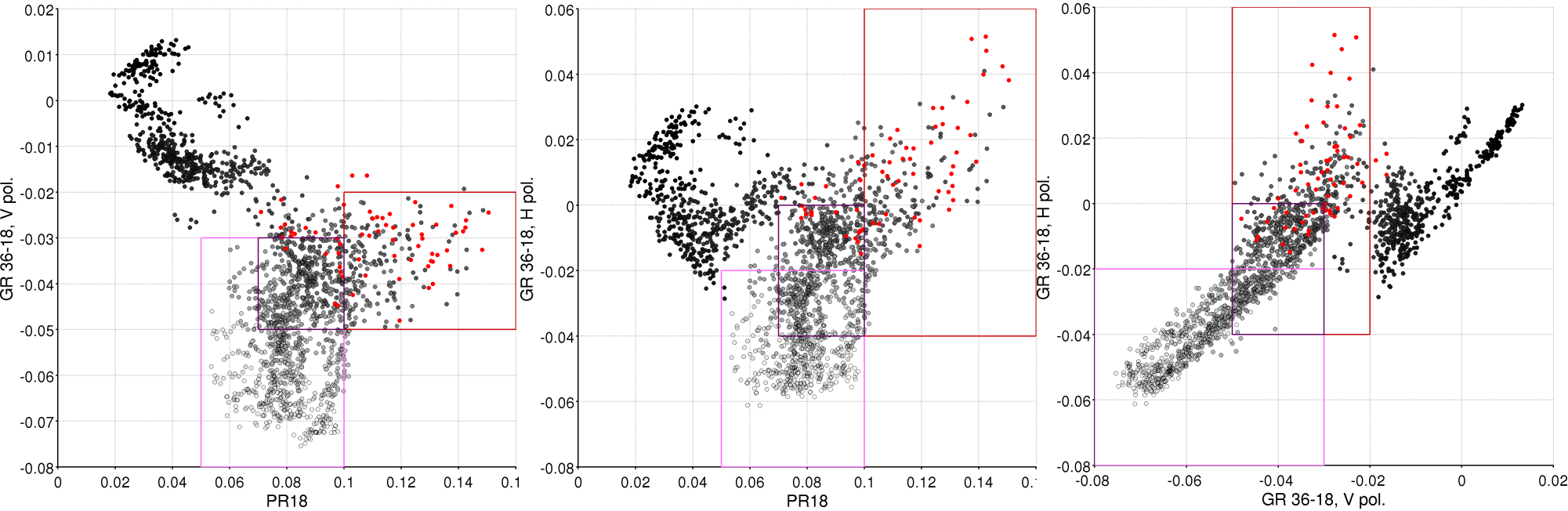
Banks Island, 2003



The day of the ROS event until 3 days after

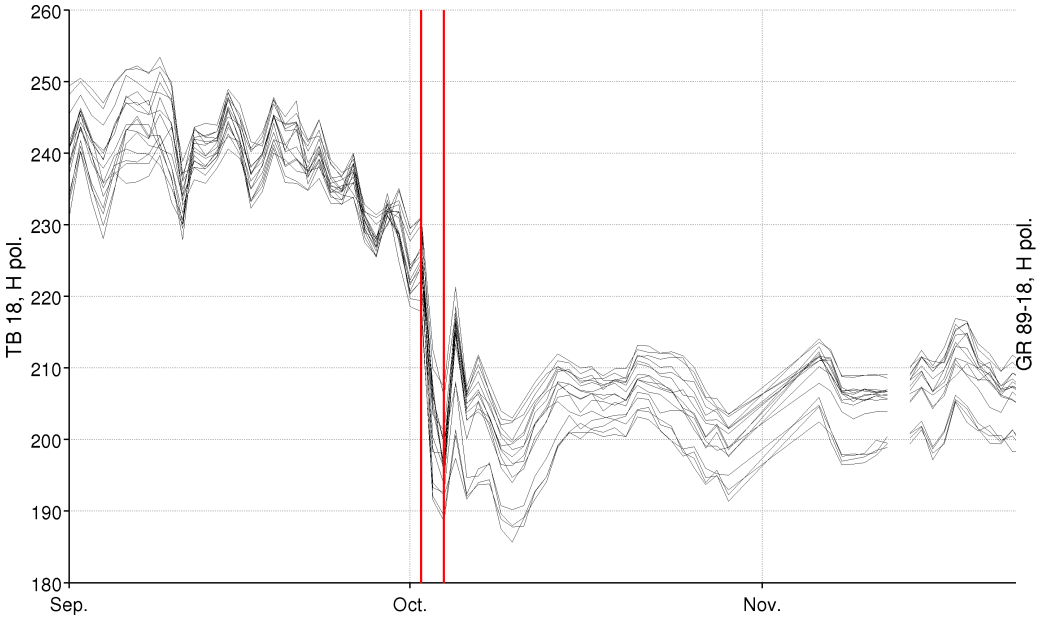
Prototype algorithm – Spectral detection

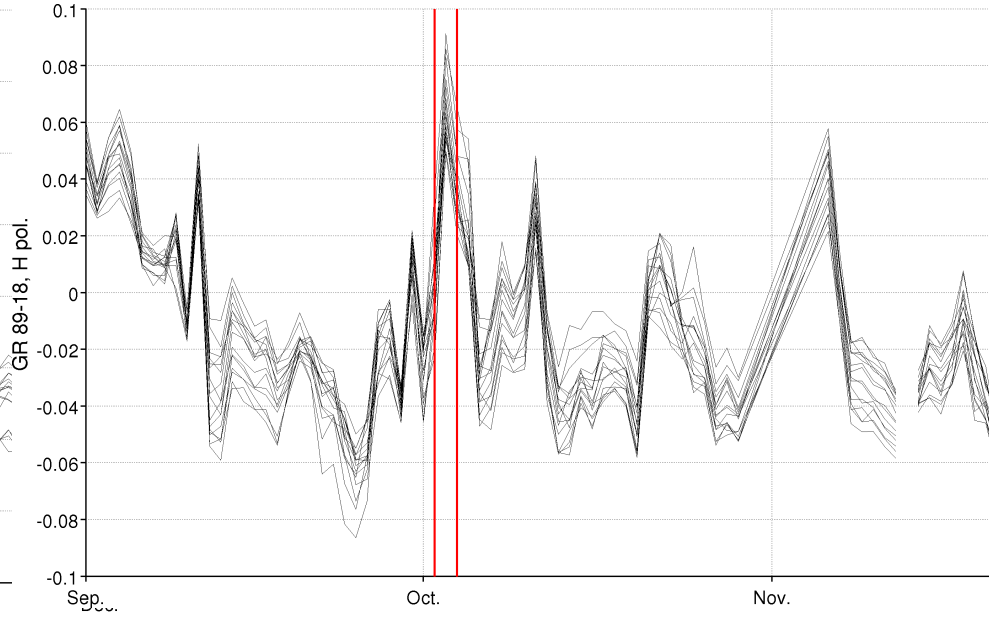
Banks Island, 2003

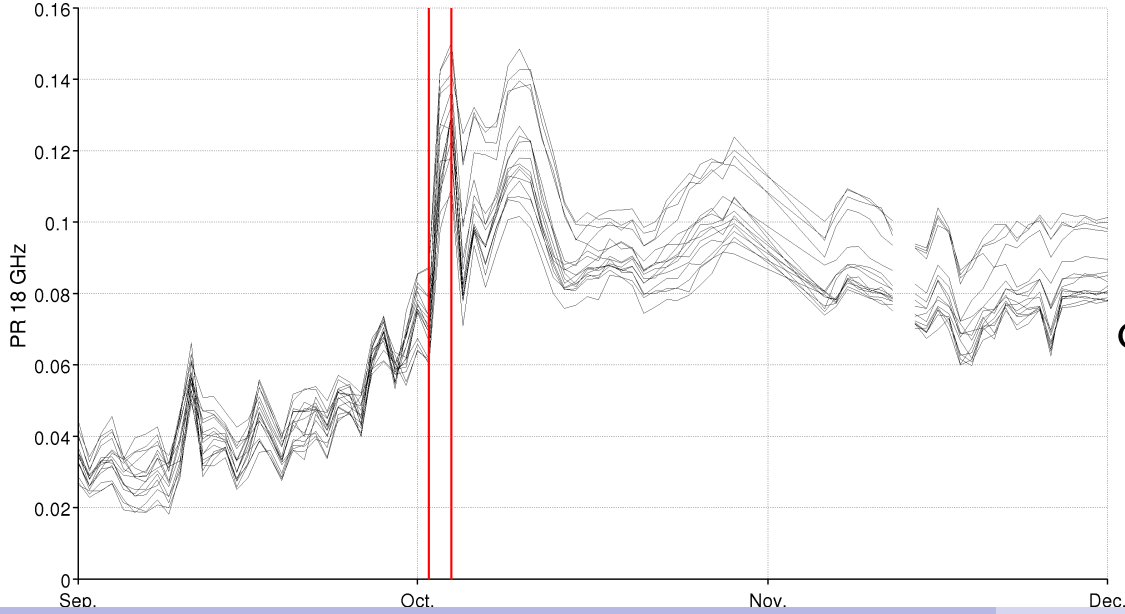


From 1 month before to 2 months after the event

Prototype algorithm – Temporal detection



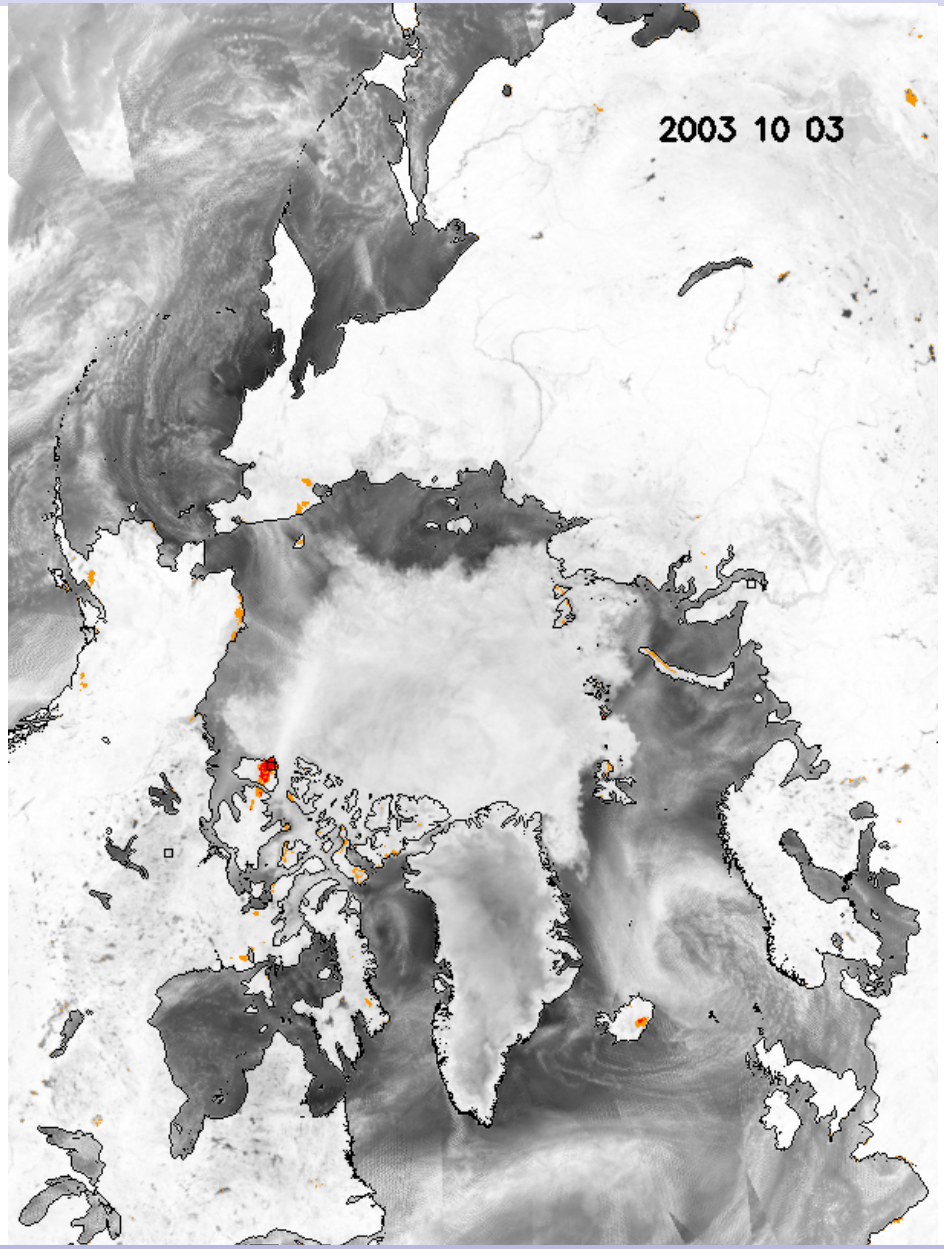




Banks Island, 2003

Temporal detection is based
on the variation from the day before

Prototype algorithm – Daily detection

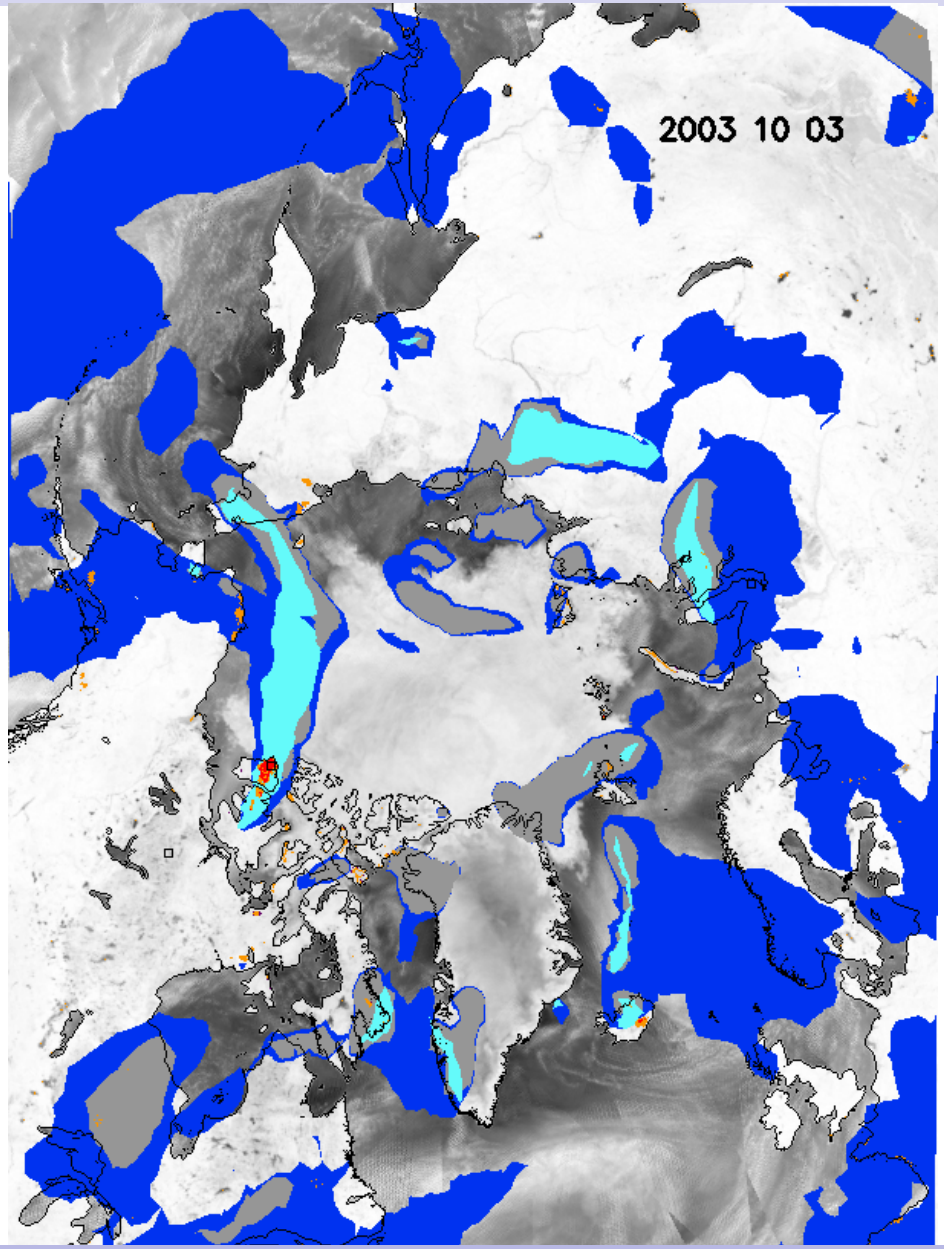


Banks Island, 2003

ROS detected with both spectral & temporal signatures

ROS with either spectral or temporal signatures

Prototype algorithm – Daily detection



Banks Island, 2003

ROS detected with both spectral & temporal signatures

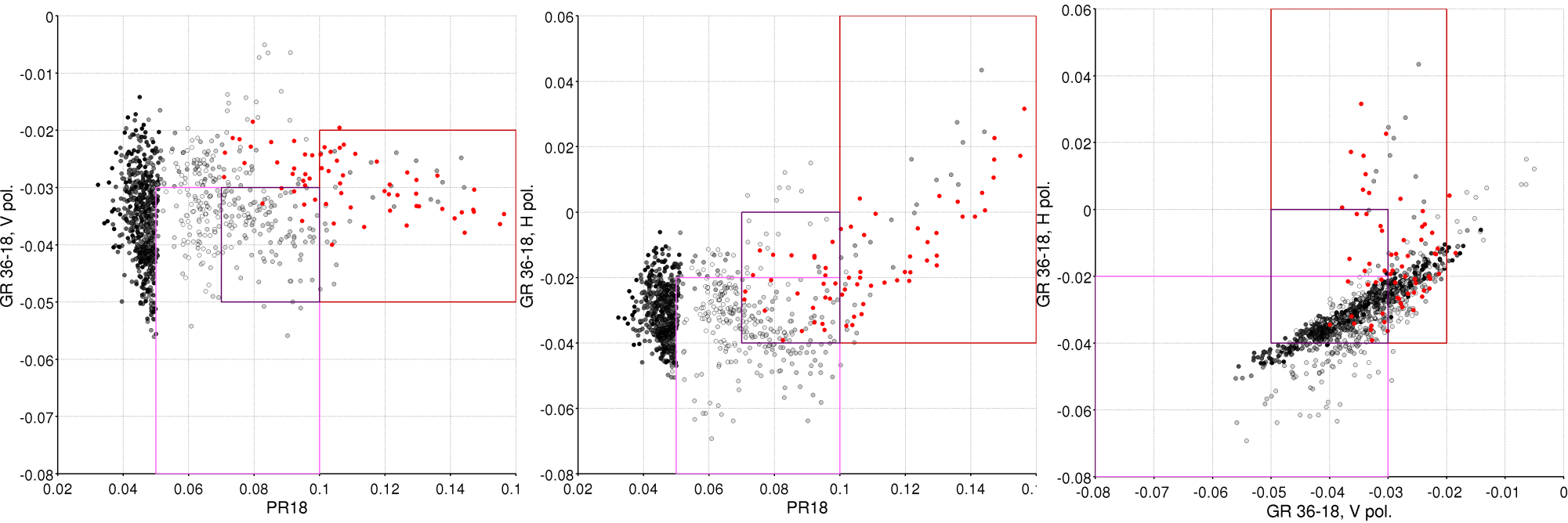
ROS with either spectral or temporal signatures

ERA-interim rainfall

ERA-interim rain in the vicinity of sub-freezing temperatures

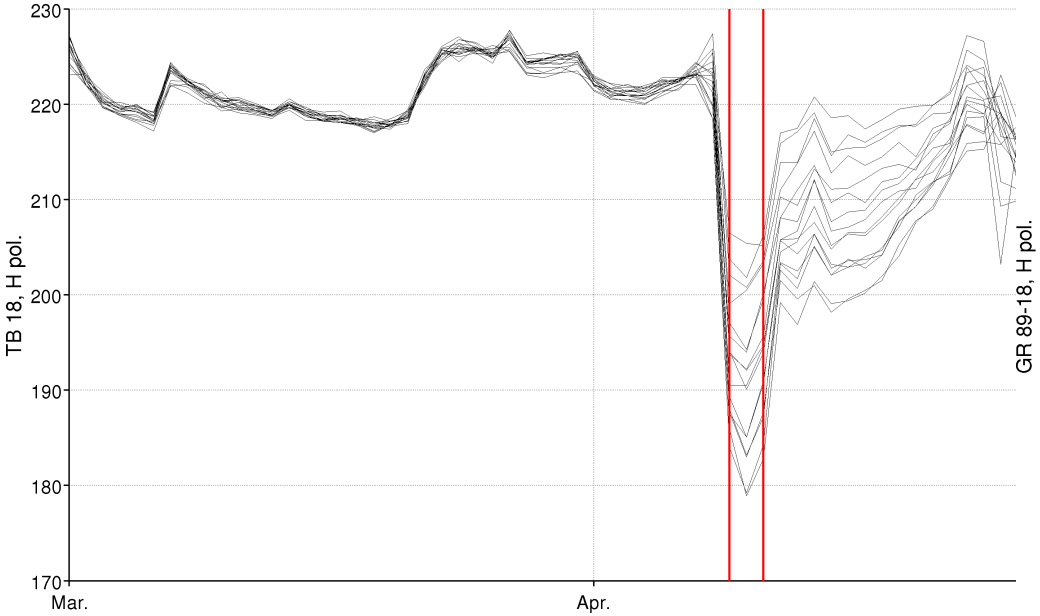
Prototype algorithm – Spectral detection

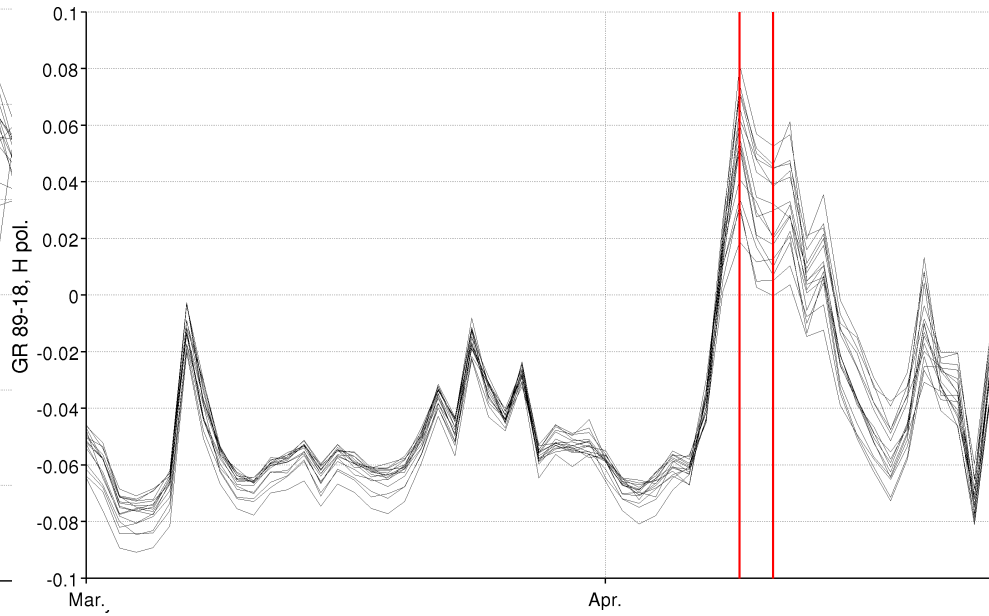
Daring Lake, 2007

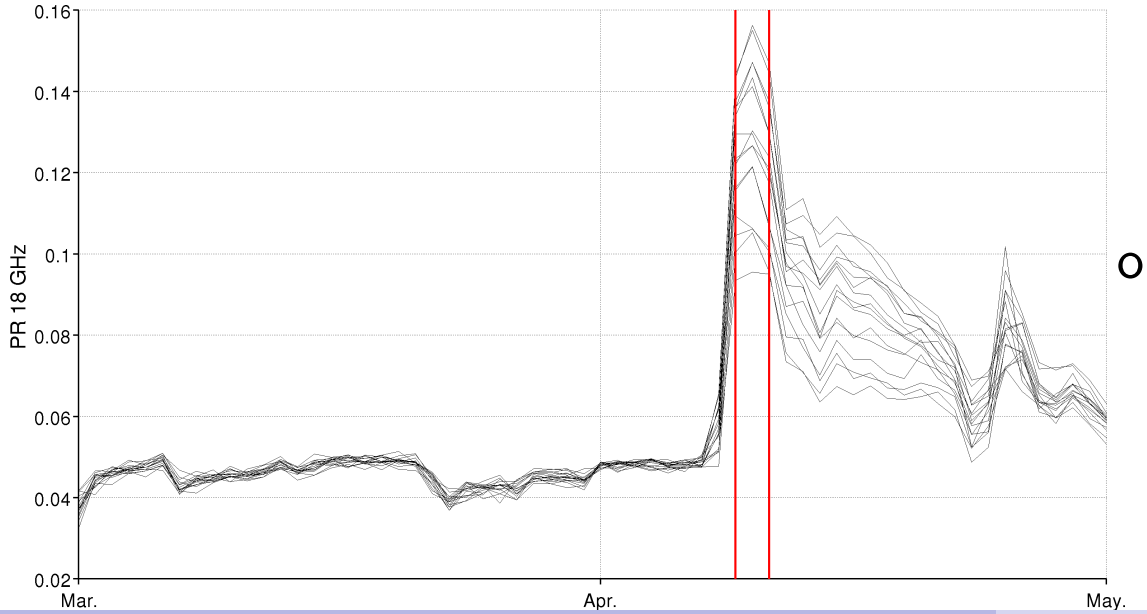


Ice lens near the surface *(Rees et al., RSE 2010)*

Prototype algorithm – Temporal detection







Daring Lake, 2007

Temporal detection is based
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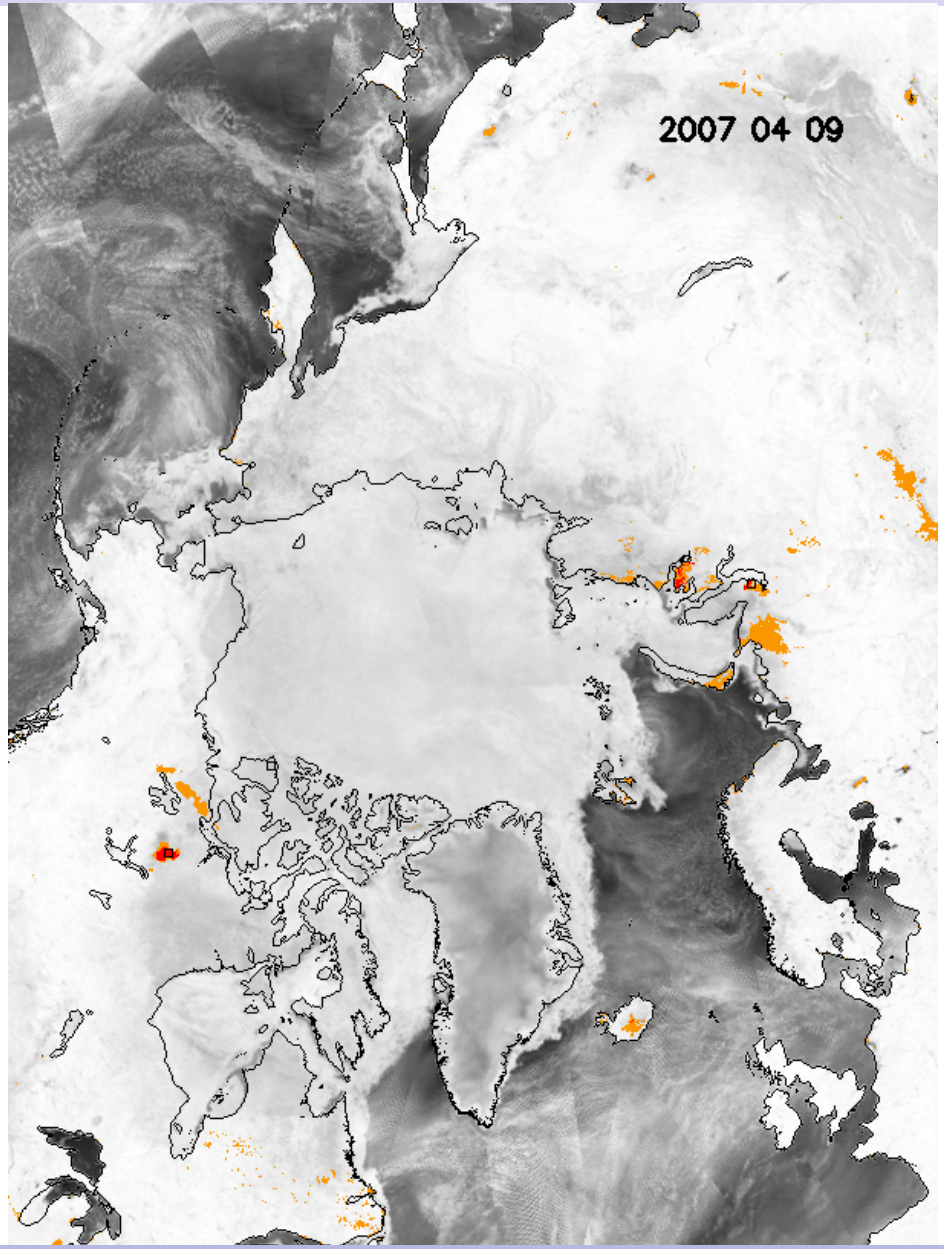
Prototype algorithm – Daily detection

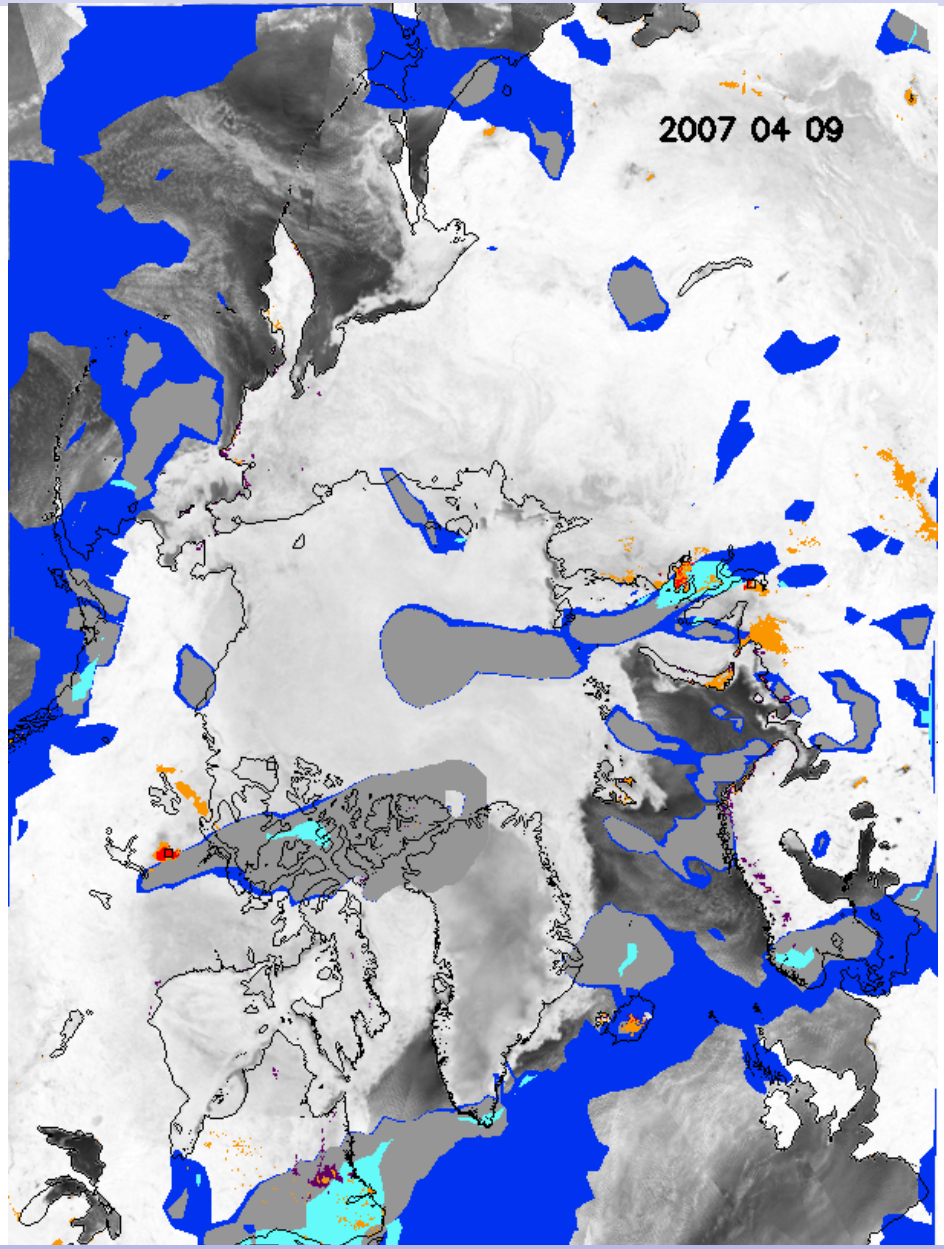


Daring Lake, 2007

ROS with both spectral & temporal signatures

ROS with either spectral or temporal signatures

Prototype algorithm – Daily detection



Daring Lake, 2007

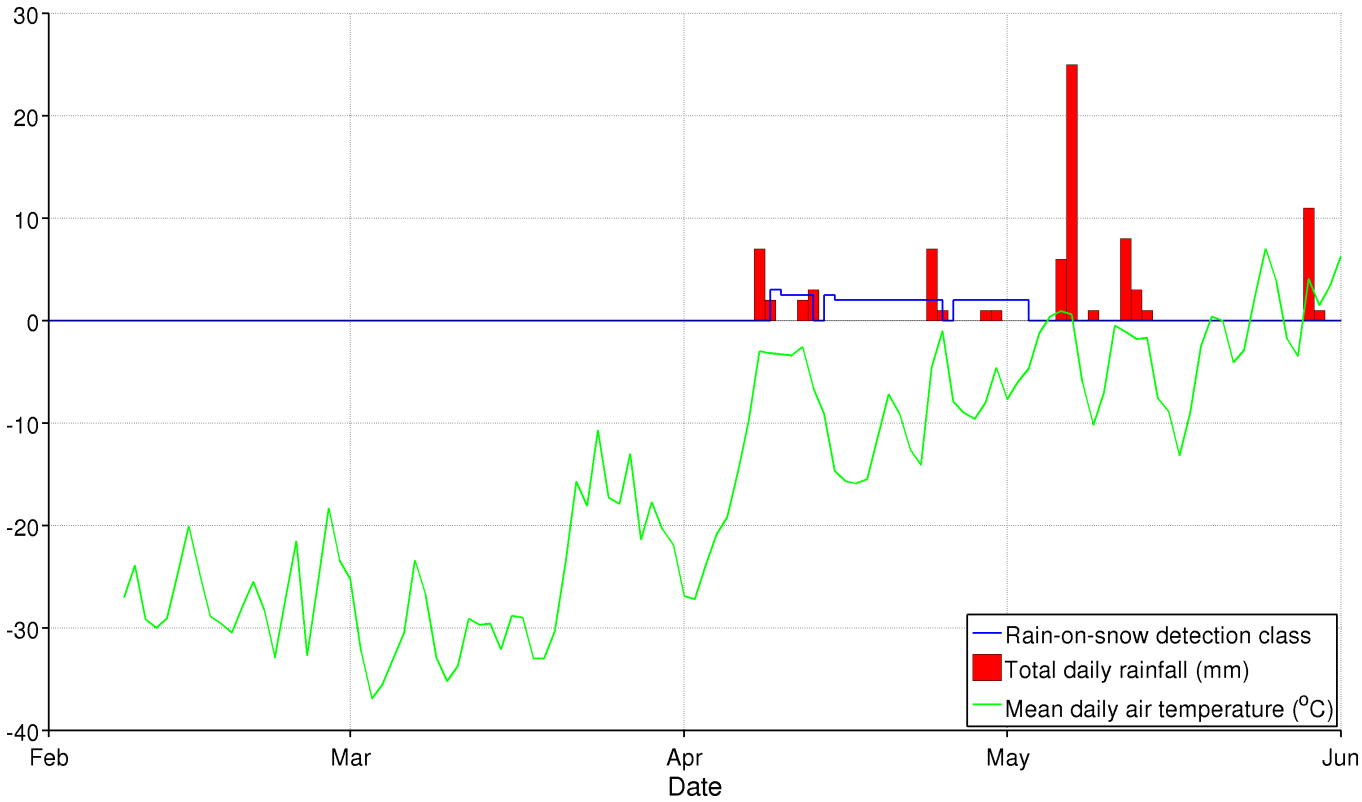
ROS with both spectral & temporal signatures

ROS with either spectral or temporal signatures

ERA-interim rainfall

ERA-interim rain in the vicinity of sub-freezing temperatures

Daring Lake, weather station data

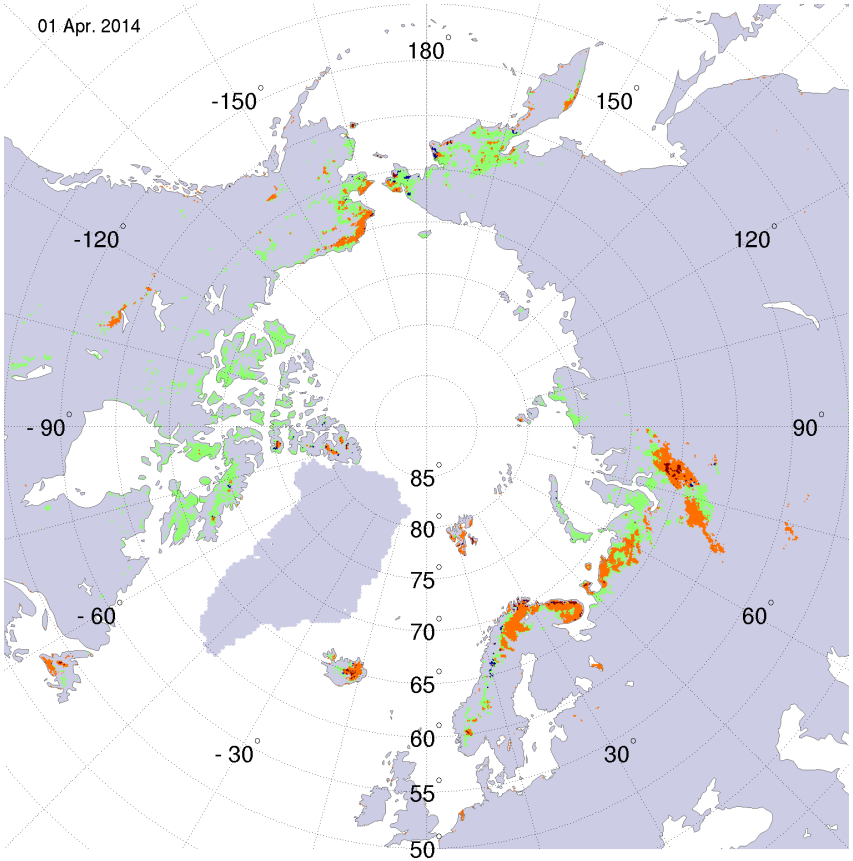


. Timely detection of the first rain-on-snow event of the season

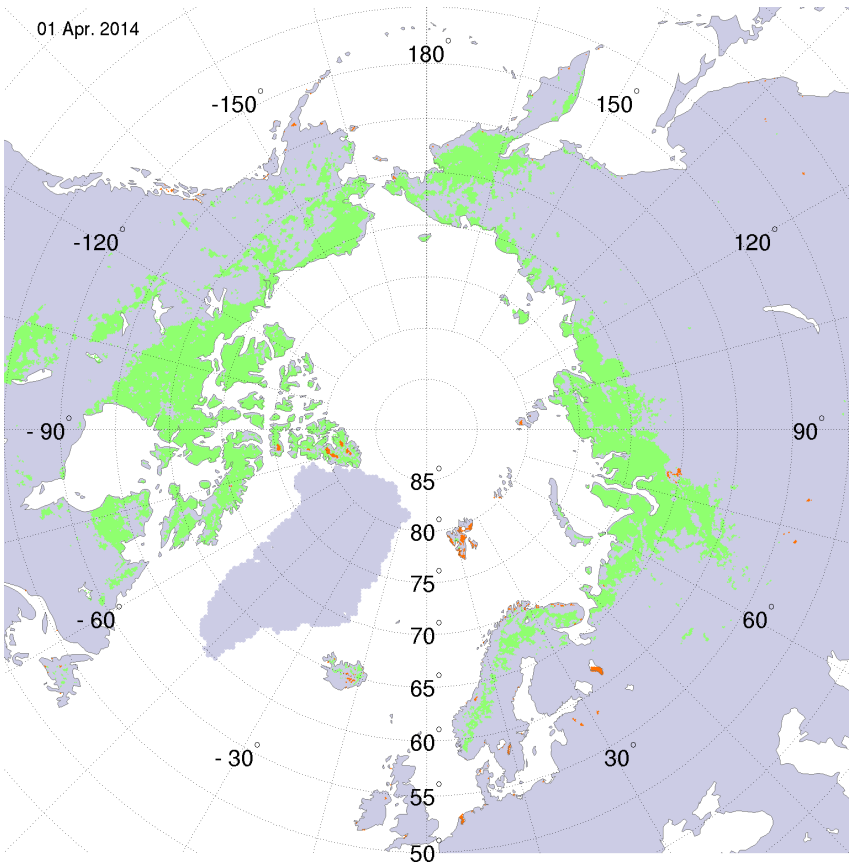
. No false detection due to melting snow ($T_{air} > 0^{o}C$)

Algorithm comparison in Spring (April 1, 2014)

Prototype algorithm



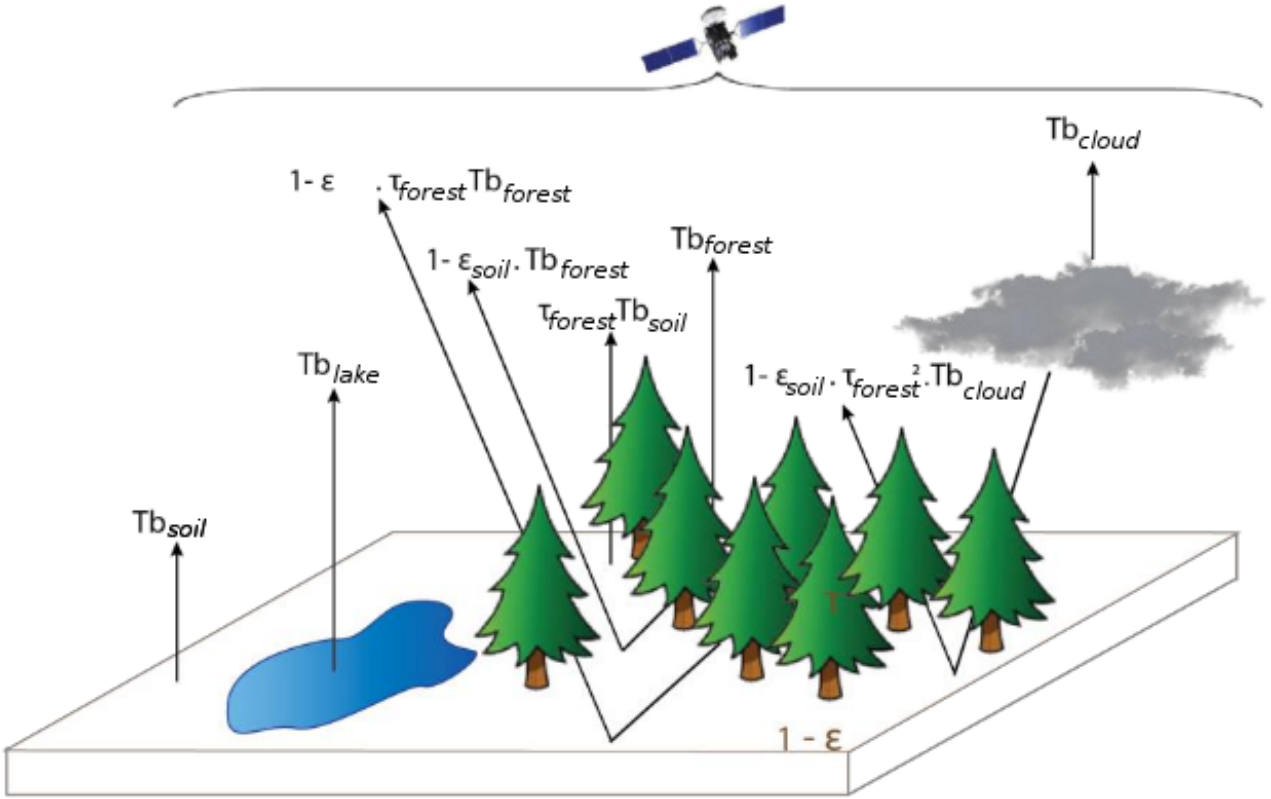
Grenfell and Putkonen (2008)



Using spectral and temporal signatures reduces spurious detections

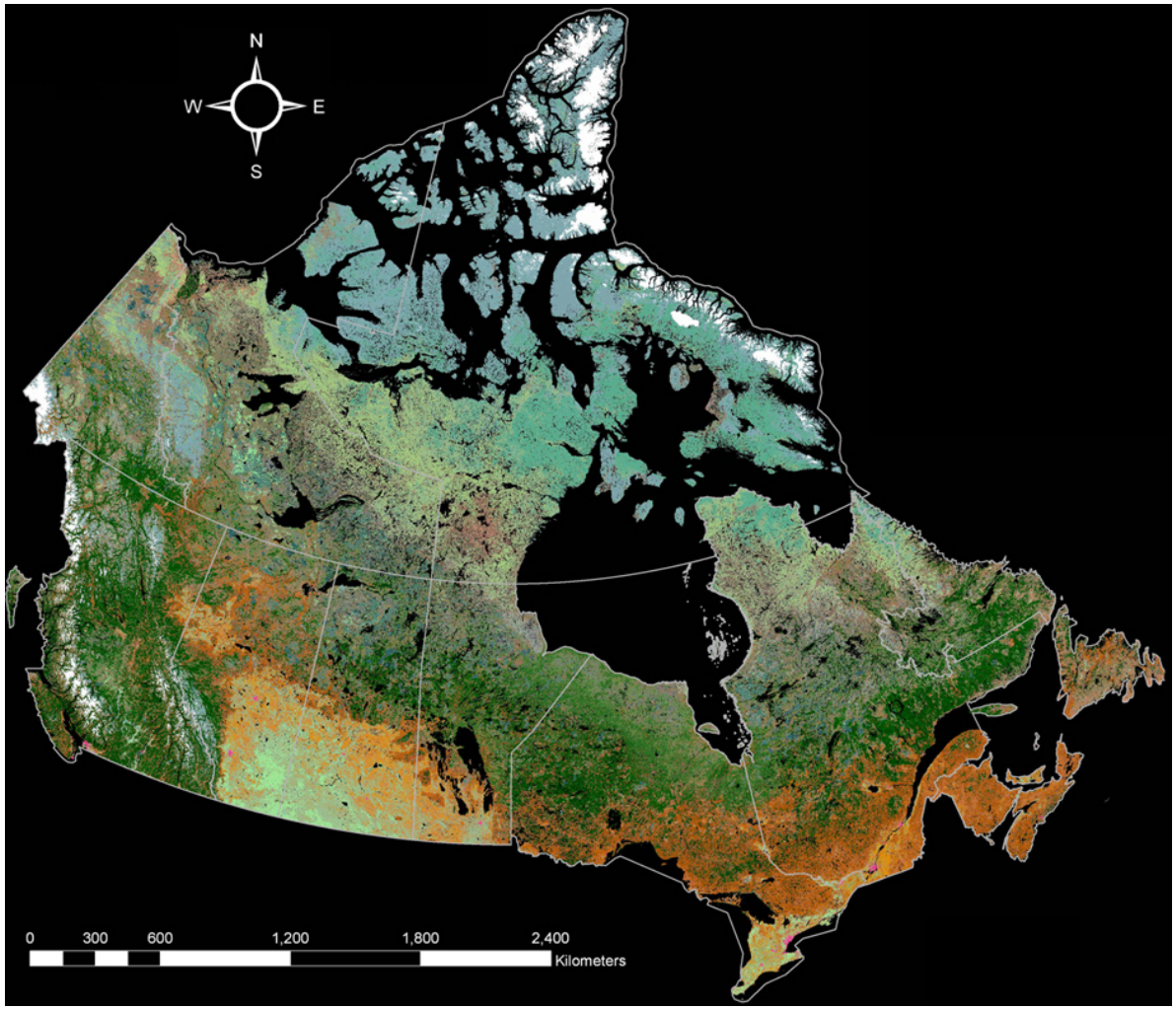
Important for a large scale application of the algorithm

Microwave radiometers have a coarse spatial resolution (5–50 km)



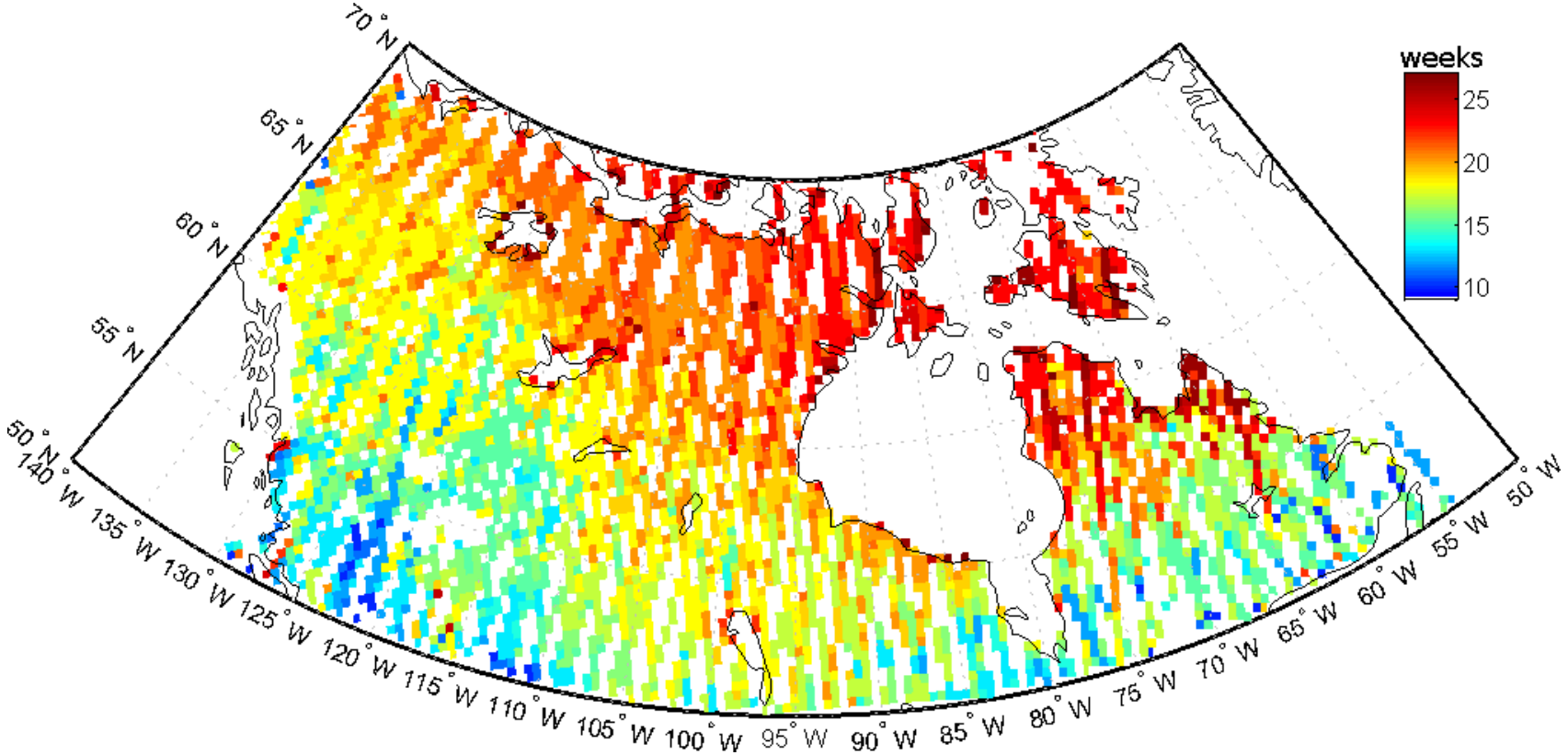
Important for a large scale application of the algorithm

Vegetation transmissivity *(Vander Jagt, RSE 2014; Langlois et al., TGRS 2011)*



Important for a large scale application of the algorithm

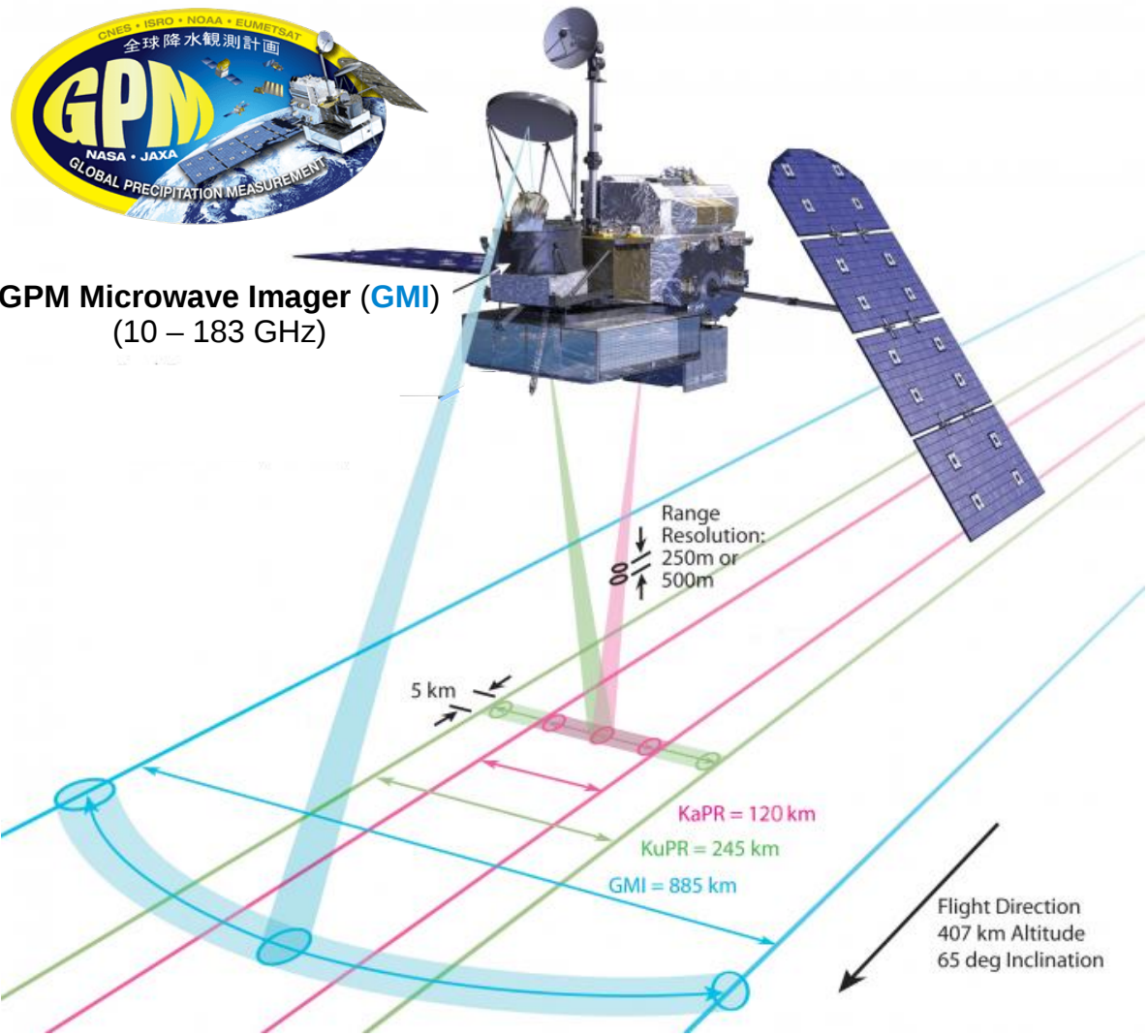
Soil physical state: freeze/thaw condition *(Roy et al., for JSTARS)*



See poster tomorrow on Aquarius products for studying the cryosphere

Global Precipitation Measurement (NASA - JAXA)

Since March 2014, GPM operates microwave radiometers & radars



Global Precipitation Measurement (NASA - JAXA)

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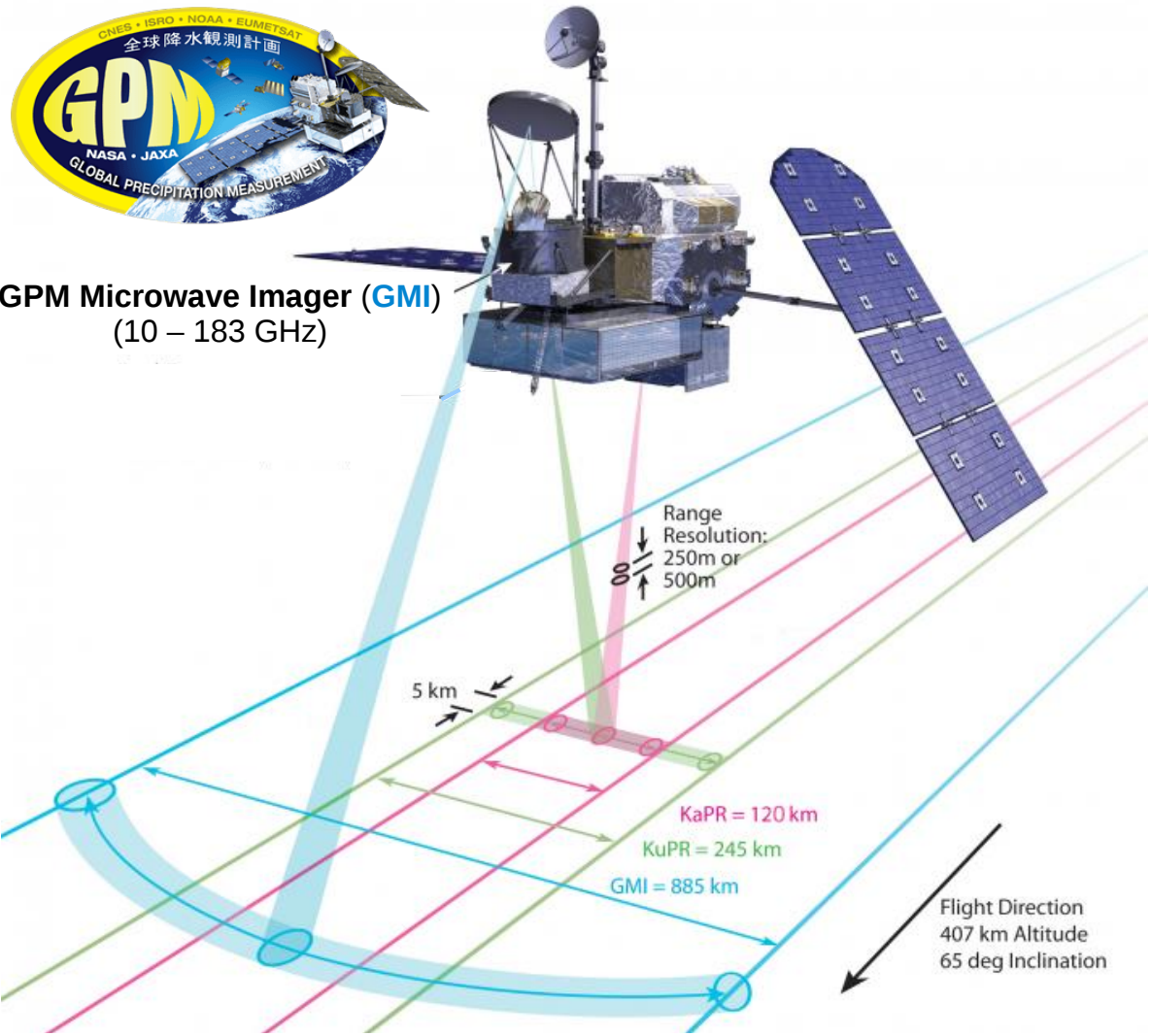
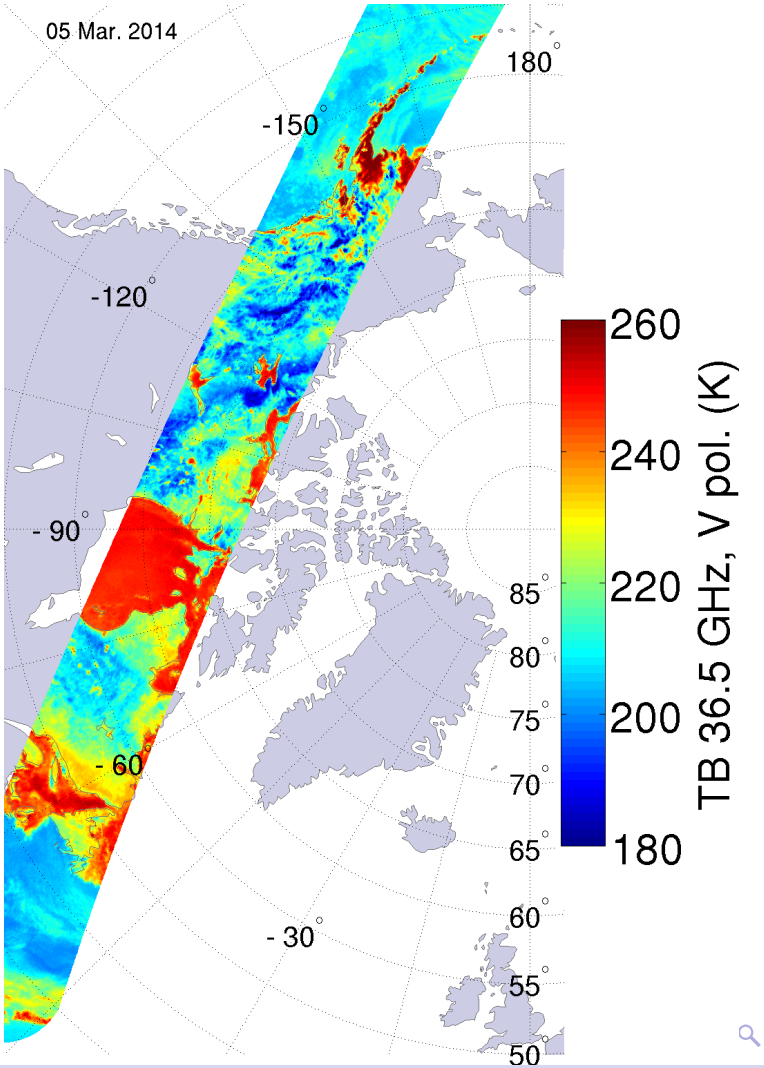
GPM Microwave Imager (GMI)
(10 – 183 GHz)





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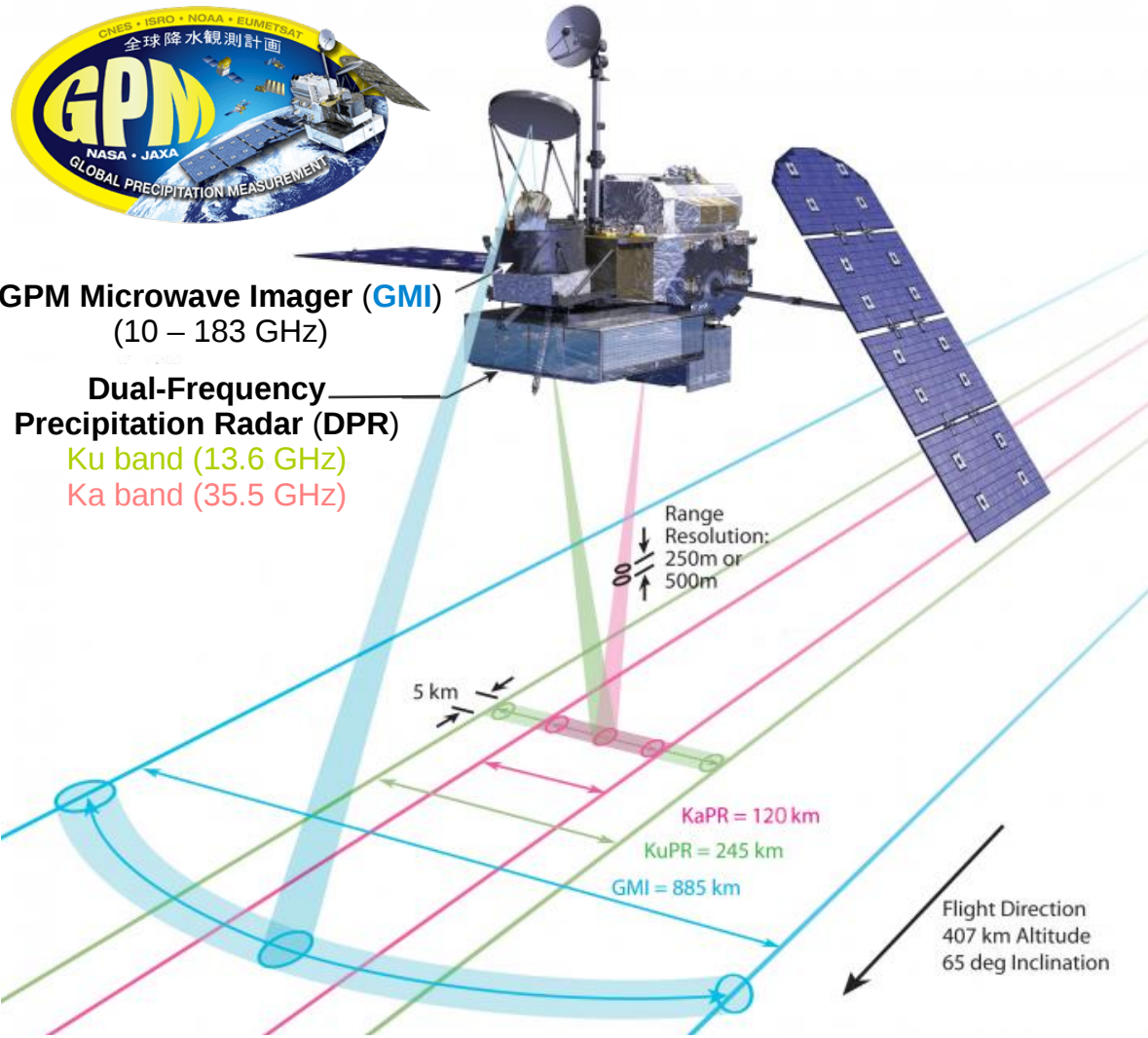

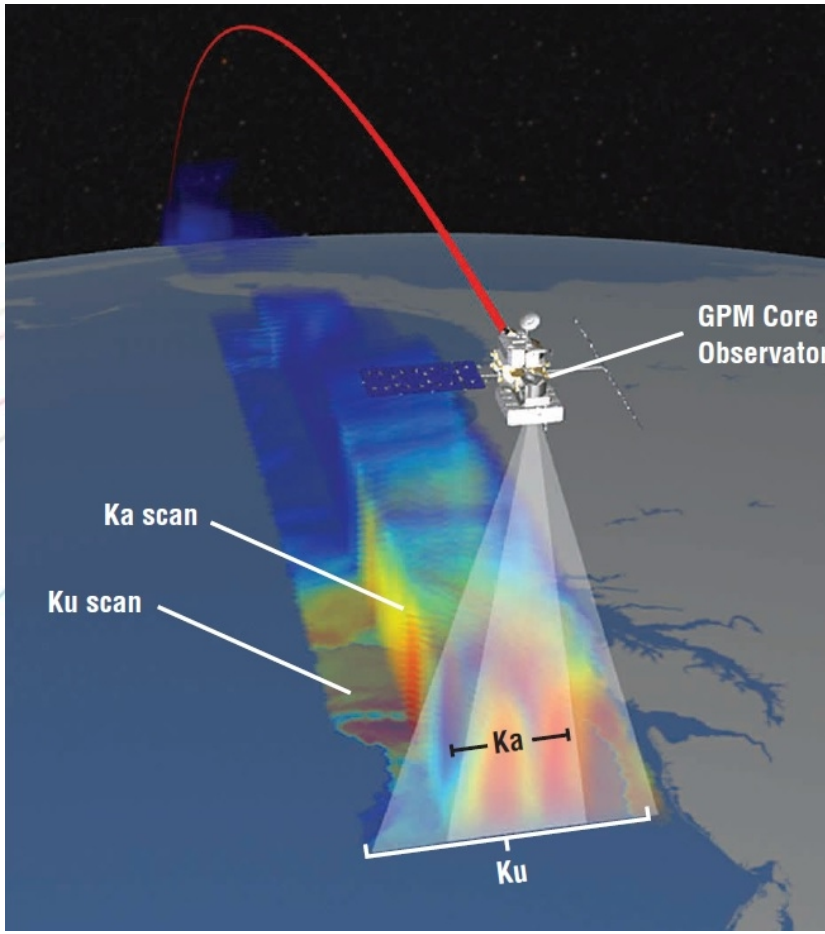

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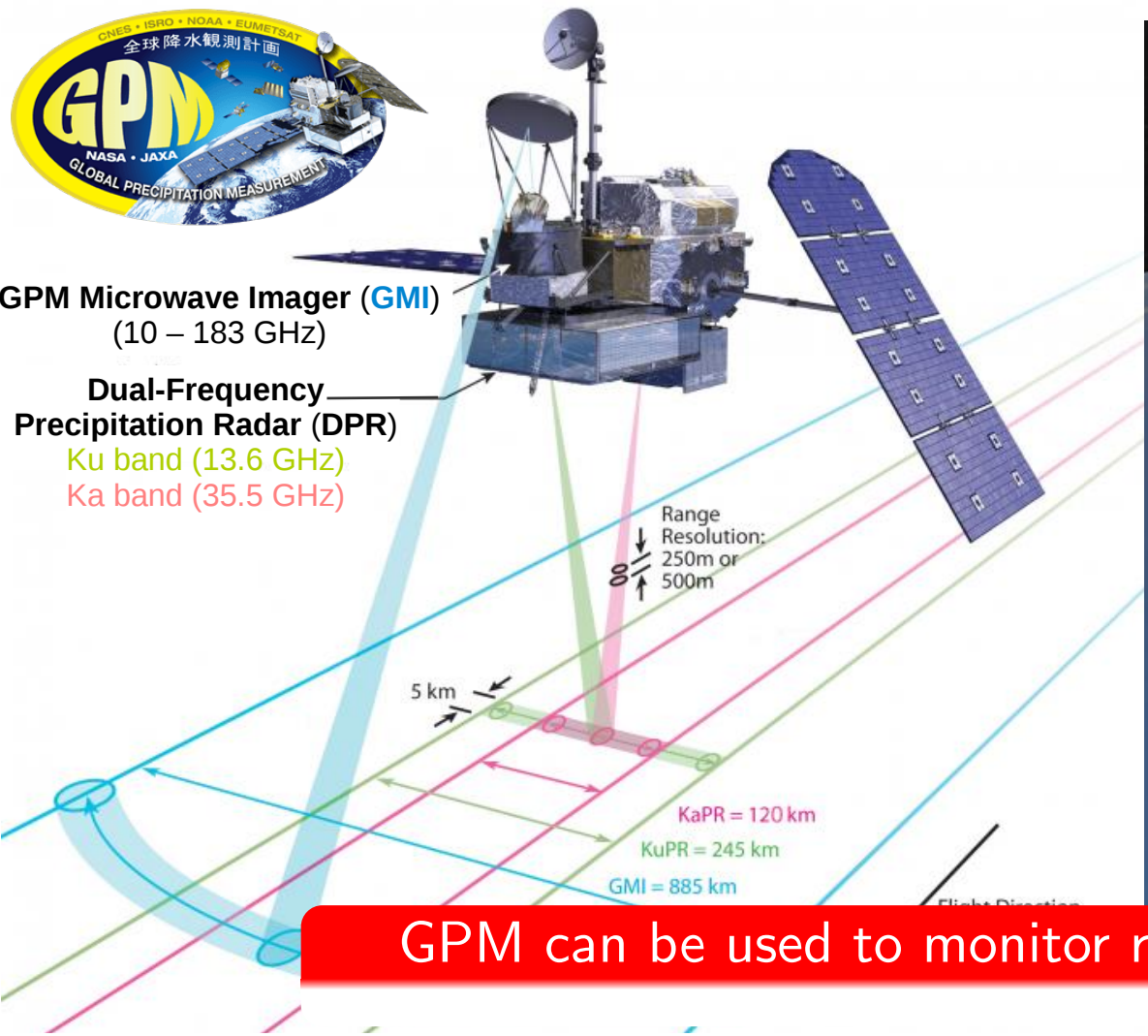
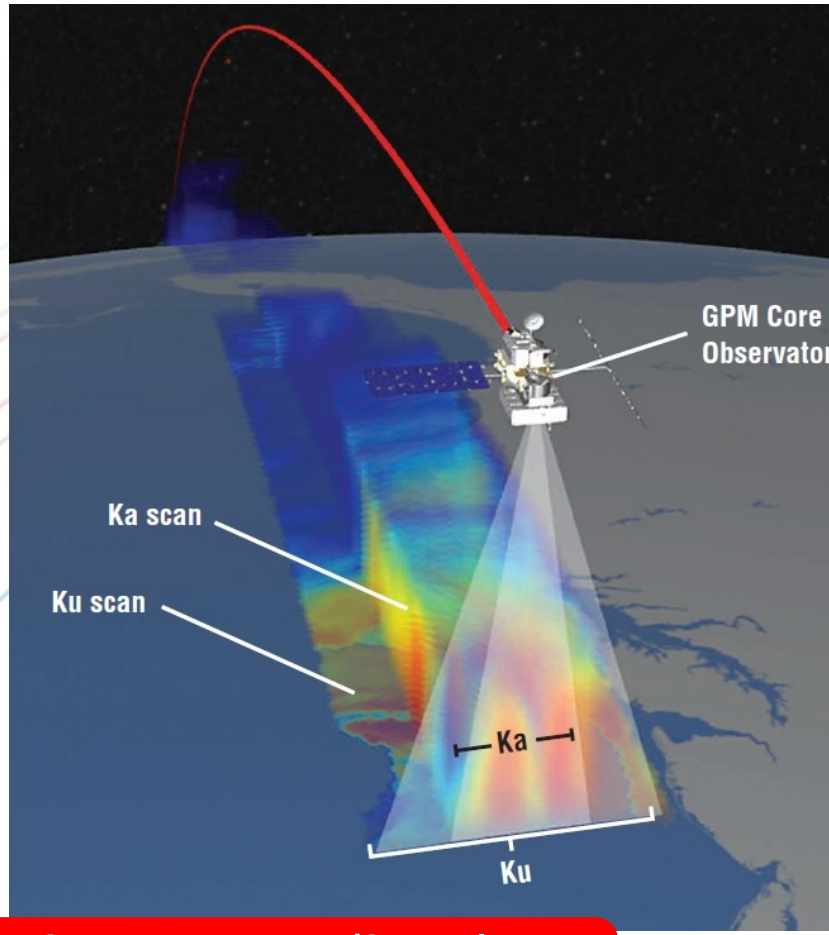


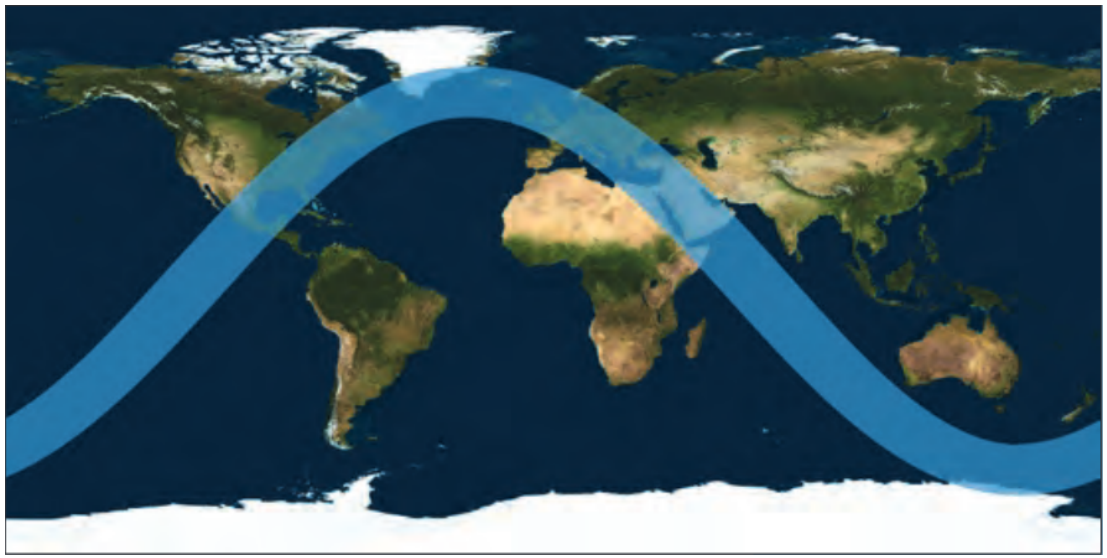


GPM can be used to monitor rain on snow directly

Global Precipitation Measurement (NASA - JAXA)

Orbit

circular
non-sun-synchronous
65° inclination
∼16 orbits per day

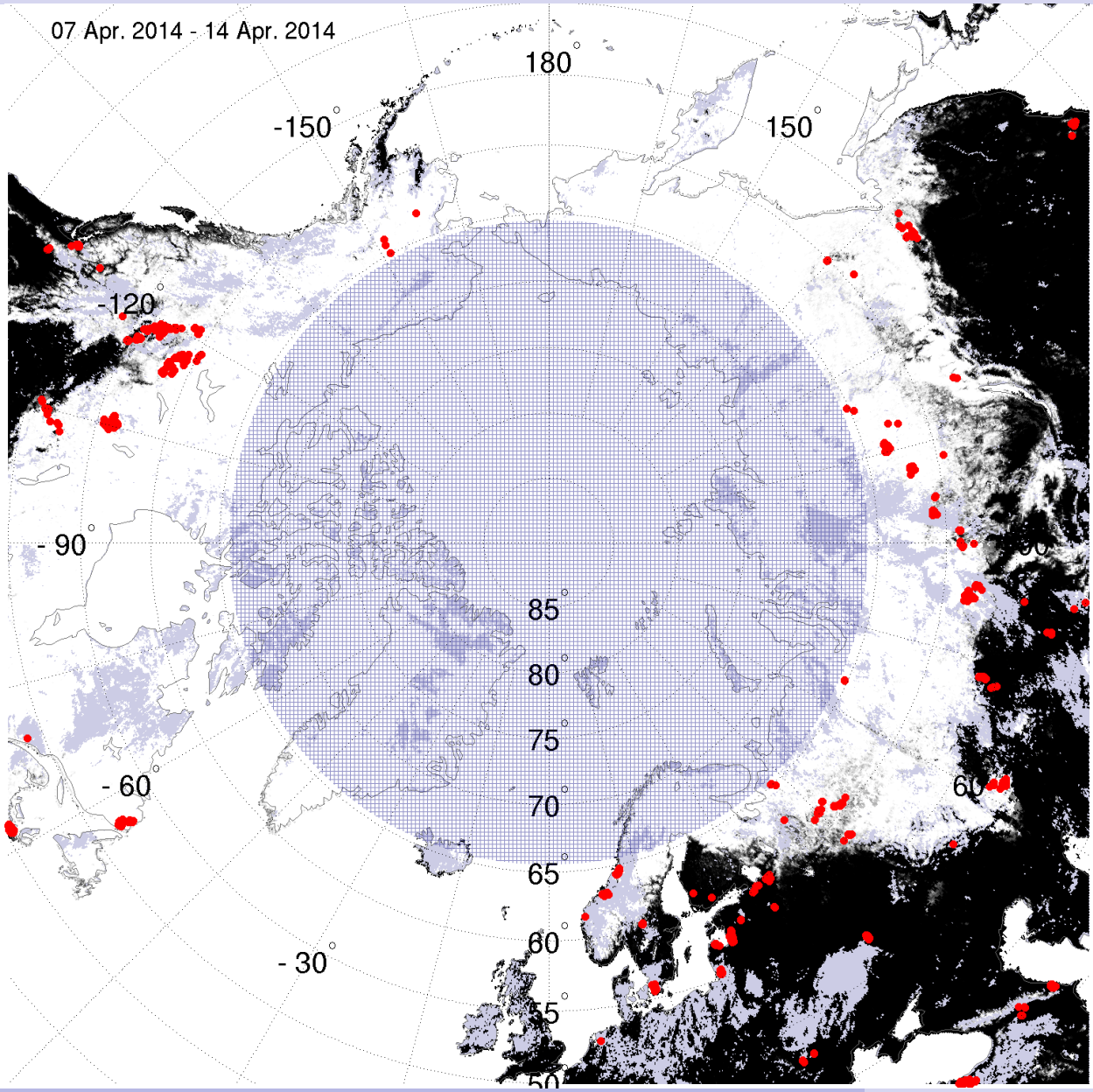


GPM data: `pmm.nasa.gov/data-access/downloads/gpm`

(Hou et al., BAMS 2014: The Global Precipitation Measurement Mission)

Level 1C products of: TB ⇝ surface state (snow/no snow)
Reflectivity ⇝ precipitation type and rate

Global Precipitation Measurement



- GMI+DPR ROS
MODIS snow cover extent

Looking forward to the first complete winter of detection

Conclusion

- Monitoring rain on snow is relevant for . wintertime climate monitoring
. supporting climate adaptation

- A prototype algorithm was developed based on spectral signatures & temporal signatures

- It is designed to detect rain-on-snow events, especially those leading to the formation of ice layering

- GPM observations provide an outstanding source of validation